

Deep Mapping of Small Solar System Bodies with Galactic Cosmic Ray Secondary Particle Showers

Completed Technology Project (2013 - 2014)



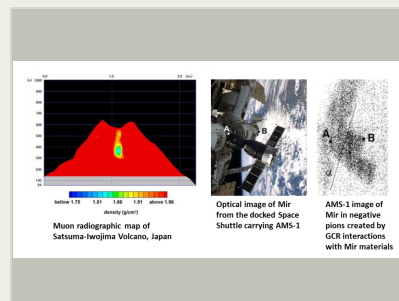
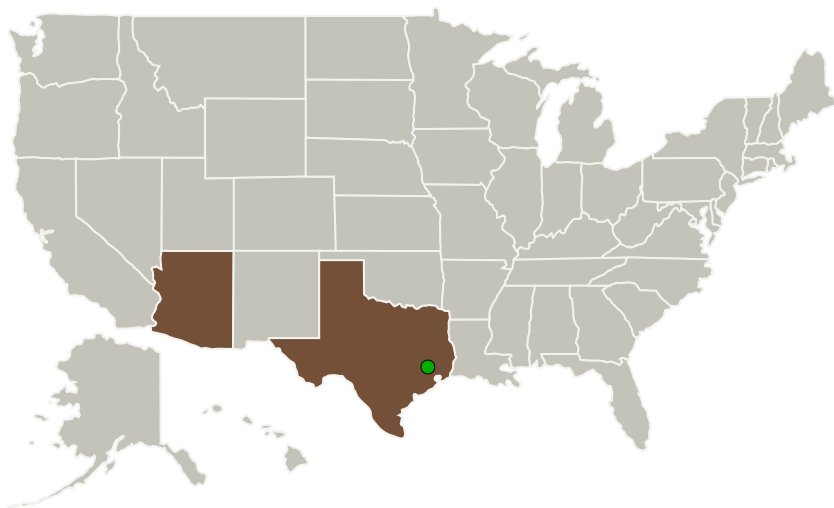
Project Introduction

We propose to develop new types of spacecraft instrumentation, data analysis, and imaging methods that enable mapping the interior of small solar system bodies (SSBs, e.g. asteroids, comet cores and near Earth objects) to unprecedented depth and detail. Our proposed method makes use of galactic cosmic ray (GCR) secondary particle shower products, such as pions and muons.

Anticipated Benefits

There are presently no established methods to directly characterize the interior structure and macroporosity of an asteroid or comet. Muography could provide a direct and cost-effective means of probing the interior density structure. Such information is important for planetary science, in situ resource utilization, mining, and planetary defense.

Primary U.S. Work Locations and Key Partners



Project Image Deep Mapping of Small Solar System Bodies with Galactic Cosmic Ray Secondary Particle Showers

Table of Contents

Project Introduction	1
Anticipated Benefits	1
Primary U.S. Work Locations and Key Partners	1
Project Transitions	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	2
Technology Areas	3
Target Destination	3
Images	4
Project Website:	4

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Organizations Performing Work	Role	Type	Location
Planetary Science Institute(PSI)	Lead Organization	Industry	Tucson, Arizona
● Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas
University of Houston	Supporting Organization	Academia	Houston, Texas

Primary U.S. Work Locations

Arizona	Texas
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Project Transitions

 **September 2013:** Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Planetary Science Institute (PSI)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

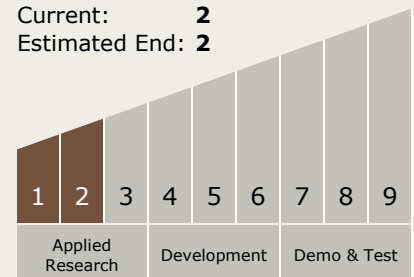
Program Manager:

Eric A Eberly

Principal Investigator:

Thomas Prettyman

Technology Maturity (TRL)

Start: **1**Current: **2**Estimated End: **2**

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✓ **April 2014:** Closed out

Closeout Summary: Our Phase I study has identified many of the challenges that must be overcome in order to use muography to characterize the interior of small solar system bodies. Future studies will focus on a thorough assessment of the muon transmitted signal in comparison to backgrounds, with the goal of establishing specific design requirements for hodoscopes. In addition, the information on content of the background sources will be examined. For example, Fig. 14 shows that the upward pion flux is comparable in magnitude to that of protons. If so, then measurements of the gross, charged-particle leakage flux may be sensitive to regolith density variations (the flux of charged pions varies with density), perhaps providing a simple means to characterize regolith density in situ along a rover traverse or from orbit. Aspects of hodoscope design need to be investigated in more detail, including modeling of instrument response to the transmitted muons and backgrounds and demonstrating that interior structure can be determined from the measurements. This activity would include the evaluation of different data acquisition scenarios and image reconstruction methods. Experimental evaluation of instrument components and subsystems can be carried out at accelerator facilities. If silica aerogel is to be used for the radiator, then some investigation of the practical limits of the index of refraction for this material is needed. A Phase II project would address most of these issues, further validating the feasibility and range of applicability of the proposed method, while advancing the instrument technology beyond TRL-2 (Mankins, 1995). Finally, we have identified a pilot mission scenario to a near Earth asteroid, which could be implemented once the instrument technology has been demonstrated. The pilot mission would use Earth-based radar to map the regolith density and shape of a selected asteroid. A spacecraft could deploy a prototype hodoscope close to the surface of the asteroid to patiently acquire the first image of the interior structure. A Phase II project would include an initial study of the feasibility of this mission scenario. While the practical implementation of muography must overcome many challenges, the potential benefits are considerable. At present, there is no established method to directly determine the interior structure of small bodies; although, active seismology (e.g. Asphaug, 2008) and radar-based methods have been suggested. Such information is important for planetary science, in situ resource utilization, mining, and planetary defense. In closing, we note that the exploration of near-Earth objects is part of the Global Exploration Roadmap for human missions beyond low-Earth orbit (GER 2013). In support of this, NASA has generated a detailed list of Strategic Knowledge Gaps (SKGs) needed to be addressed to support human exploration. Macroscopic porosity of small body interiors is among these SKGs (NASA SBAG 2014). Interior structure is also critical to determine modes of planetary defense against a potentially hazardous object (e.g., Asphaug et al. 1998).

Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
 - └ TX09.4 Vehicle Systems
 - └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

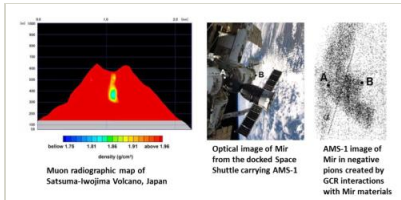
Others Inside the Solar System

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Images



13738-1390334632190.jpg

Project Image Deep Mapping of Small Solar System Bodies with Galactic Cosmic Ray Secondary Particle Showers

(<https://techport.nasa.gov/image/102073>)

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>